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PARASITES OF THE PINK BOLLWORM IN HAWAII

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HOST PLANTS OF THE PINK BOLLWORM

Incidental to other work of the Bureau of Entomology in Honolulu during 1918 and 1919, observations were made on the pink bollworm, *Pectinophora gossypiella* Saunders, and on the habits and effectiveness of certain of its parasites. Although Busck's observations in Hawaii (*3, p. 358–359*) [1] indicated that the pink bollworm was there confined to the genus Gossypium, and that Fullaway's record (*5, p. 17*) that he had reared it from milo, *Thespesia populnea*, was doubtful, it has since been shown that not only is *T. populnea* its food plant but that two other plants, *Hibiscadelphus hualalaiensis* and *Hibiscus youngianus*, are also its hosts in Hawaii. Bridwell (*9, p. 373*) reported breeding *P. gossypiella* from *T. populnea* on a small island on the windward side of Oahu. Giffard (*7, p. 413*) reared adult *P. gossypiella* in September, 1917, from fruits of the native tree *Hibiscadelphus hualalaiensis* collected at Puuwaawaa, island of Hawaii. One adult was reared by Swezey (*12, p. 8; 13, p. 29*) from a seed capsule of *Hibiscus youngianus*, collected at Waimalu, Oahu, in April, 1921, and three adults from fruits of the same plant, collected near Hilo, Hawaii, July, 1921.

During September, 1918, the writer made a study of *T. populnea* to determine its susceptibility to attack by *P. gossypiella*. From 34

[1] Italic numbers in parentheses refer to "Literature cited," p. 14.

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pink bollworm eggs deposited by moths in confinement on pods of this tree, 4 adults were reared. The high mortality was probably due to starvation caused by the inability of the newly hatched larvae to tunnel through the shell of the pods, which became very hard and dry shortly after removal from the tree. An examination of 155 milo pods, collected at the Government nursery, King Street, and at the Hawaii Agricultural Experiment Station, Pensacola Street, gave the following results: Ten empty pupal shells, 2 living pupae, 4 mature larvae, and one half-grown larva of *P. gossypiella*. One pupa was killed during removal from the seed pod, but from the other pupa and the 4 mature larvae, 5 adults of the pink bollworm were reared. From 442 milo seed pods, collected in various localities on Oahu, 68 adult *P. gossypiella* were reared, together with various parasites. These records indicate that *T. populnea* is frequently used as a food plant by this moth.

In Hawaii, as in many other parts of the world where cotton is grown, *P. gossypiella* is the most destructive cotton insect. Records were made of the average number of pink bollworms per boll in the various lots of cotton collected. Although these records were made both from green bolls and from those which had begun to open, the average infestation figures from large numbers is a good indication of the extent of attack. Occasionally a collection of bolls would be entirely free from infestation. Such collections, however, were always made from a single plant, or a very small group of plants, which were in every case isolated from other cotton. The heaviest infestation was obtained from one lot of 22 bolls, collected at the experiment station in September, 1918. This lot contained 113 pink bollworm larvae, or an average of 5.1 larvae per boll. The total of 8,744 bolls, which were collected during 1918 and 1919, contained 12,985 caterpillars of *P. gossypiella*, an average of 1.5 per boll. While the average number of larvæ per boll may seem small, it was difficult to find a well-developed boll not infested in most of the cotton patches visited. Parasitism did not reduce the infestation to a noticeable extent.

PARASITISM

P. gossypiella is attacked in Hawaii by seven parasites, all of which are general moth parasites, and are listed as follows: Two Braconidae, *Chelonus blackburni* Cameron, which develops in 8 different hosts in Hawaii (*11*), and *Microbracon mellitor* Say (*M. pembertoni* Bridwell), which has been reared from 4 hosts (*1, p. 21; 2, p. 115*); two Ichneumonidae, *Pimpla hawaiiensis* Cameron, which has been reared from 10 hosts, and *Pristomerus hawaiiensis* Ashmead, from 5 hosts (*11*); one bethylid, *Perisierola emigrata* Rohwer, which is reported by Bridwell (*1, p. 21; 2, p. 115*) as breeding on three species of moths; and two chalcids, *Chalcis obscurata* Walker, from 13 hosts (*11*), and *Stomatoceras pertorvus* Girault, which has been reported by Busck (*3, p. 359*), but has not been reared by the writer.

TABLE 1.—*Parasitism of Pectinophora gossypiella in Hawaii*

Month	Number of gossypiella larvae	Percentage of parasitism						
		Chelonus blackburni	Microbracon mellitor	Perisierola emigrata	Pristomerus hawaiiensis	Pimpla hawaiiensis	Chalcis obscurata	Total parasitism
1918								
March	503	6.2	0	0	0	0.2	0.2	6.6
June	71	0	9.9	1.4	1.4	0	0	12.7
July	3,664	18.1	3.8	.3	.5	0	0	22.7
August	1,332	.1	7.9	.3	1.1	0	0	9.4
September	921	.2	.8	.1	.4	0	0	1.5
October	246	0	2.4	0	0	0	0	2.4
November	804	.1	.1	0	.5	0	0	.7
December	293	3.1	11.3	.3	.3	0	0	15.0
1919								
May	1,341	0	.1	0	.1	.1	0	.3
June	1,140	0	.1	.2	.4	0	.4	1.1
July	1,536	0	0	.1	0	0	.1	.2
August	953	0	0	.1	0	.1	.1	.3
September	181	0	0	0	0	0	0	0
Total, 1918, 1919	12,985	5.45	2.33	.17	.38	.03	.06	8.42

Table 1 shows the degree of parasitism by each of the six species of parasites reared by the writer, over monthly periods during 1918 and 1919. These records were obtained by collecting cotton bolls in various localities on the island of Oahu and holding them in breeding jars until all adult parasites and moths had emerged. These adults were removed daily and counted, forming the basis for the figures in the table. Of the 12,985 caterpillars under observation, 8.42 per cent were parasitized. The low degree of control accomplished by the six species of parasites probably results from the fact that two of the six species parasitize at least three other species of moths, and the other four parasitize 2, 9, 7, and 12 other species. None of the six is a specific parasite of *P. gossypiella*, and only occasionally is a high degree of parasitism observed.

The highest parasitism for any monthly period was for July, 1918, when 22.7 per cent of 3,664 larvæ were parasitized. This rate of parasitism was abnormal, and was due to *Chelonus blackburni*, which parasitized 18.1 per cent; while that of the other three species reared amounted to only 4.6 per cent. The high parasitism by *C. blackburni* for this month is accounted for by the exceptionally large number, 664, which was reared from 400 bolls, containing 1,431 caterpillars, collected on the grounds of the experiment station. Parasitism of 46.7 per cent in this lot of bolls was higher than that in any lot collected, and was divided as follows: *C. blackburni* 46.2 per cent, *Microbracon mellitor* 0.4 per cent, and *Perisierola emigrata* 0.1 per cent. This record of parasitism is considered abnormal because only 1 other adult *C. blackburni* was reared during July, 1918, from 1,801 bolls, containing 2,233 *P. gossypiella* larvæ, collected in other localities; also, because during the other 12 months only 44 adults of *C. blackburni* were reared from the remaining 9,321 larvæ collected, 2,014 of which came from the experiment station grounds. The reason for the exceptionally high parasitism by *C. blackburni* in this one collection of cotton bolls has been a matter

of conjecture. It is probable that some other host of this parasite was abundant near this particular lot of cotton while the bolls were developing, and that *C. blackburni* developed in large numbers at its expense, emerging when the pink bollworms on the cotton were susceptible to the maximum parasitization.

Although the record of parasitism by *C. blackburni* for the entire period was higher than that for any of the other five, it should not be considered the most valuable under Hawaiian conditions. The greater part of its work was confined to one small lot of bolls, and it was found only occasionally during the remainder of the period. In the opinion of the writer, *Microbracon mellitor* was the most valuable parasite of *P. gossypiella* observed. It was reared from pink bollworm larvæ from all localities on Oahu. Although the total parasitism by it was less than half of that by *C. blackburni*, its attack was general throughout the cotton collected and its percentage of parasitism was not due to an unusual parasitism in any one lot collected. During 7 of the 10 months in which either of these species was secured, parasitism by *M. mellitor* was greater than that by *C. blackburni*, and during 1 month it was the same. For only 2 months of the 10 was parasitism by *C. blackburni* greater. Since *M. mellitor* is capable of attacking its host more effectively than *C. blackburni* throughout the major part of the year and since it is established over a larger area, it is considered the more valuable.

In the course of these observations on infestation and parasitism some studies were made of the biology of *Microbracon mellitor* and *Perisierola emigrata*. *M. mellitor* (Bracon sp.) was first reared from *P. gossypiella* in Hawaii by Fullaway (*6, p. 228*). It was considered an undescribed species by workers in Hawaii, and in 1918 was described by Bridwell (*1, p. 21; 2, p. 115*) and named *Microbracon pembertoni*. It was later discovered by Muesebeck (*8, p. 65*) that this insect agreed with the description of *Bracon mellitor* Say (*10, p. 256*), and consequently *pembertoni* is considered a synonym of *mellitor*. Notes on the life history of this species are given below. Busck (*3, p. 359*) has published a brief account of the biology of *P. emigrata*, but some additional notes on its development have been made and are given herein.

MICROBRACON MELLITOR SAY

ADULT

The adult of *Microbracon mellitor* was described and named by Say (*10, p. 256*) in 1836. Individuals vary considerably in size, depending upon the amount of food material available from the host. From small caterpillars, adults not over 1.5 mm. in length have been reared, but the usual length of those developing on *P. gossypiella* larvae is 4 mm. The parasite in this stage is strong and vigorous and is able to maintain itself well under adverse conditions. Of 31 adults retained in glass vials without food, one lived 18 days, one 15 days, and three 14 days. The majority, however, died from 6 to 9 days after emergence. When held in confinement and fed on a mixture of honey and water they survived from 24 to 102 days. Five females, confined in glass vials for the purpose of obtaining daily rates of oviposition, and fed daily on honey and water, survived 24, 33, 40, 41, and 102 days respectively.

MATING

Nearly all activity prior to and during mating is on the part of the male. When approximately 1 inch from the female, the male begins a steady and rapid fluttering of the wings, runs rapidly to the female and pounces upon her back, landing on the upper surface of her closed wings. The head of the male is usually above the thorax of the female, causing the abdomen of the male, which is an insect only about two-thirds as long as the female, to be directly above that of the female. While in this position the male rubs the head of the female lightly with his antennae. Fluttering of the wings continues while the insects are in this position as well as during copulation, but is intermittent. A distinct but slight pause in the fluttering occurs about every half second. If the female desires to mate, the male, a few seconds after mounting her, bends his abdomen around one side of the abdomen of the female until the tip enters the genital opening. Should the female not desire to mate she very easily repels the male by raising her wings to an angle of about 45°, elevating the male to such a distance from her body that copulation is impossible. Copulation may continue from 15 to 30 seconds. Of five matings under observation, copulation continued 15 seconds in three instances and 25 and 30 seconds in the other two. The female usually terminates copulation by pushing the male away with her hind legs, although the male occasionally detaches himself from the female voluntarily.

Mating may occur at any time throughout the adult stage, often taking place immediately after emergence. Unmated females are capable of parthenogenetic reproduction, although the progeny are probably always males, as in the case of many other braconids which reproduce in a similar manner. One unmated female deposited 79 eggs throughout her lifetime, from which 28 adults were reared, all of which were males. The numbers of each sex produced by adults which have mated are about equal under field conditions in Hawaii. Of 306 adults reared from pink bollworm larvæ in cotton collected in the field, 149, or 48.7 per cent, were males, and 157, or 51.3 per cent, females.

OVIPOSITION

Oviposition may begin within 2 days after emergence of the adult, but often does not begin for 5 to 7 days. Of eight females under observation in glass vials, two began oviposition 2 days after emergence, one 3 days, one 4 days, two 6 days, and one 8 days. All of these parasites had a constant supply of host larvæ from the time of emergence. Table 2 shows the number of eggs deposited daily by eight females confined in glass vials and supplied with pink bollworm caterpillars daily. It was possible to get complete records from only three of the eight females, Nos. 3, 4, and 6. The host caterpillars severed, with their mandibles, the ovipositors of Nos. 1, 2, 5, and 7 before complete records were obtained, and No. 8 escaped. The three complete records show that this parasite in confinement may oviposit almost daily throughout its life, and that one adult may deposit as many as 213 eggs. No. 6 deposited 63 eggs in four consecutive days, January 8 to 11, inclusive. This high rate of oviposition apparently overtaxed its strength to such an extent that

only three more eggs were deposited before death. In nine instances the host larva was paralyzed when no eggs were deposited.

TABLE 2.—*Daily rate of oviposition of Microbracon mellitor on larvæ of Pectinophora gossypiella*

Date of oviposition	Eggs deposited by female No.							
	1	2	3	4	5	6	7	8
1918								
Dec. 6	2	----	----	----	----	----	----	----
7	3	----	----	----	----	----	----	----
8	8	----	----	----	----	----	----	----
9	6	----	----	----	----	----	----	----
10	4	----	----	----	----	----	----	----
11	10	----	----	----	----	----	----	----
12	14	----	----	----	----	----	----	----
13	19	----	----	----	----	----	----	----
14	8	----	----	----	----	----	----	----
15	8	----	----	----	----	----	----	----
16	14	----	----	----	----	----	----	----
17	(1)	----	----	----	----	----	----	----
23	----	5[2]	----	----	----	----	----	----
24	----	6	----	----	----	----	----	----
25	----	4	----	----	----	----	----	----
26	----	1	5	----	----	----	----	----
27	----	0	5	----	----	----	----	----
28	----	1	6	----	----	----	----	----
29	----	1 1	4	3	----	----	----	----
30	----	----	8	0	----	----	----	----
31	----	----	12	6	----	----	----	----
1919								
Jan. 1	----	----	8	6	2	3	----	----
2	----	----	7	3	5	3	2	2
3	----	----	10	15	3	8	2	6
4	----	----	6	8	6	6	4	4
5	----	----	4	8	7	6	6	9
6	----	----	5	10	9	16	9	6
7	----	----	2	5	7	8	8	14
8	----	----	3	9	8	15	11	10

Date of oviposition	Eggs deposited by female No.							
	1	2	3	4	5	6	7	8
1919								
Jan. 9	----	----	4	2	5	15	14	12
10	----	----	3	0	0	18	(1)	8
11	----	----	2	2 0	2	15	----	4
12	----	----	4	2 0	3	3	----	14
13	----	----	5	2 0	7	2 0	----	6
14	----	----	2	2 0	9	2 0	----	7
15	----	----	4	1	2	2 0	----	7
16	----	----	2 0	2	1	0	----	9
17	----	----	2 0	6	1	0	----	9
18	----	----	2	3	2	0	----	5
19	----	----	4	7	(1)	0	----	5
20	----	----	2	8	(3)	(3)	----	(4)
21	----	----	1	12	----	----	----	----
22	----	----	2	16	----	----	----	----
23	----	----	1	6	----	----	----	----
24	----	----	0	7	----	----	----	----
25	----	----	(3)	13	----	----	----	----
26	----	----	----	11	----	----	----	----
27	----	----	----	8	----	----	----	----
28	----	----	----	13	----	----	----	----
29	----	----	----	7	----	----	----	----
30	----	----	----	4	----	----	----	----
31	----	----	----	3	----	----	----	----
Feb. 1	----	----	----	2	----	----	----	----
2	----	----	----	2	----	----	----	----
3	----	----	----	3	----	----	----	----
4	----	----	----	4	----	----	----	----
5	----	----	----	(3)	----	----	----	----
Total	----	----	121	213	----	116	----	137

[1] Ovipositor bitten off by host larva.
[2] Host larva paralyzed but no eggs deposited.
[3] Died.
[4] Escaped.

Before *M. mellitor* deposits its egg it always stings and paralyzes the host caterpillar. The egg is deposited directly upon the larva or in the cotton lint surrounding it. Two eggs were observed in a cotton boll, which were adhering to the cotton fiber about one-eighth inch away from the paralyzed caterpillar. The question arose as to the ability of the larvae hatching from these eggs to reach their host. To determine this question 10 eggs were placed in a glass tube 2½ inches distant from a paralyzed caterpillar. Two of the larvae hatching from these eggs were able to crawl to the caterpillar and begin feeding, which would indicate that larvae from eggs not deposited on the host have the ability to reach the host and continue their development.

The excitation to attack in *Microbracon mellitor* seems to occur only when the host larva is inclosed by some covering. In nature, the caterpillar is stung and oviposition occurs while it is within the cotton boll. In the laboratory also attack and oviposition upon caterpillars within bolls were secured without difficulty; but no notice was taken of caterpillars that had been removed from the bolls and allowed to crawl about in the parasite cages. Oviposition was readily obtained by inclosing a caterpillar in a gelatin capsule about one-

half inch long, such as physicians use for administering powders, and which had been perforated in several places by a needle. When a larva inclosed in this manner was placed in a cage with gravid females, the stimulus to attack was immediately evident. A female would soon locate one of the perforations, through which it would sting and paralyze the larva. That the stimulus was due to a moving larva within a covering is further indicated by the fact that *M. mellitor* readily stung, and oviposited upon, maggots of the melon fly, *Bactrocera cucurbitae* Coq., which were similarly placed in gelatin capsules. The poison injected by the parasite killed instead of paralyzing the maggots, which soon began to decompose, and the larvæ which hatched from the parasite eggs could not develop. The stimulus to attack was also shown in the case of larvæ of the Mediterranean fruit fly, *Ceratitis capitata* Wied., in fruits of *Mimusops elengi*. This fruit is small, usually less than 1 inch in length, about one-half inch in diameter, and has a thin tough skin. One of these fruits, the skin of which had been perforated with a needle, and which contained 9 *C. capitata* larvæ, was placed in a cage with female parasites. Within two hours all the maggots had been stung and killed; but no eggs were found in the fruit.

By using transparent gelatin capsules, as previously described, and glass sterilizing tubes as parasite cages, the processes of stinging, paralyzation, and oviposition were clearly visible through a binocular microscope. When a perforation in the capsule was located, the parasite inserted its ovipositor rather cautiously until it came in contact with the caterpillar. The ovipositor was then given a quick thrust and immediately withdrawn. During the fraction of a second required for the thrust the skin of the caterpillar was pierced and enough poison injected to cause paralyzation. After the ovipositor was withdrawn the parasite rested several minutes and again inserted the ovipositor, pricking the caterpillar several times to ascertain the degree of paralyzation. As soon as the larva became quiet an egg was deposited upon it.

The parasite stings the host larva in any spot which may come in contact with its ovipositor, for it is not necessary to select any particular spot on the body to cause paralyzation. The sting causes the larva to struggle violently at first, but its struggles become more and more feeble until it is capable of only slight movement. Complete paralyzation does not occur, and the larva is able to move slightly after the parasite egg has hatched and the resulting larva has been feeding for a day or two. Of 22 pink bollworm caterpillars under observation, the time required between the insertion of the sting and maximum paralyzation ranged from 5 to 21 minutes, with an average of 10 minutes.

EGG

The newly deposited egg (fig. 1) is 1.2 mm. in length and its greatest width is less than one-fifth of its length. The surface is smooth and glistening. The color is clearly hyaline at the posterior third and the anterior fourth, and dull white between. In form, the egg is curved ventrally, the posterior end is attenuated and slightly curved, and the anterior tip is broadly rounded. Observations of 54 eggs recorded in Table 3 show the duration of the egg stage, under

laboratory conditions with a range in temperature of 71° to 86° F., to be from 18 to 28 hours. Under field conditions the egg stage would be lengthened some 3 or 4 hours, since the mean temperatures in the open average about 4° less than those recorded in the laboratory.

TABLE 3.—*Duration of egg stage of Microbracon mellitor*

Number of eggs under observation	Length of egg stage	Temperature		
		Maximum	Minimum	Mean
	Hours	*°F.*	*°F.*	*°F.*
6	18	86	80	83
3	19	86	78	82
7	20	86	78	82
1	28	86	78	82
20	19	85	79	82
1	21	85	79	82
1	22	85	79	82
1	25	86	76	81
4	24	80	72	76
2	25	80	72	76
1	24	79	73	76
5	25	79	73	76
2	27	77	71	74

LARVA

Immediately after hatching, the larva crawls about over its host until it finds a suitable location, whereupon it begins feeding. It feeds only at the surface at all times during its development, sucking juices through minute lacerations made with its mandibles in the skin of its host. It does not necessarily feed in one spot, but may frequently move about to a new location. The ability of the newly hatched larva to crawl about over the host caterpillar enables it to locate other larvæ of the same species; thereupon a combat occurs, resulting in the death of one and assuring an ample food supply for the survivor.

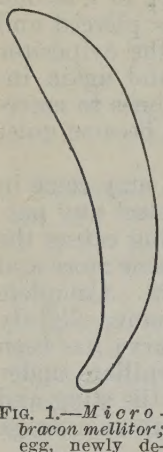

FIG. 1.—*Microbracon mellitor;* egg, newly deposited, 1.2 mm. long

That the tendency toward self-preservation is strong was shown by observations of 7 *Pectinophora gossypiella* larvæ, each of which contained several eggs of *Microbracon mellitor.* About six hours after hatching, 2 living parasite larvæ were found on each of 4 of the caterpillars and 5, 4, 4, and 3 dead parasite larvæ, respectively. On each of the remaining caterpillars 1 living parasite larva was found and 6, 3, and 2 dead larvæ, respectively. During the six hours four actual combats were observed where one larva was killing another. Three of the 4 caterpillars, which contained 2 living parasite larvæ, produced 2 adult *M. mellitor* each. Although this parasite is normally a solitary feeder, one large host caterpillar, like that of *P. gossypiella*, may support and produce two parasites.

The primary larva (fig. 2) when first hatched is 1.2 mm. long, translucent white in color, and has 14 segments including the head. The head is inconspicuous, of about the same color, texture, and softness as the rest of the body, and bears a pair of elongate papillæ on the latero-frontal portion. The mandibles are small, short, almost

straight, sharply pointed, and well chitinized at the distal half. The middle portion of the lateral and dorsal areas of each segment bears short, sharp spines. The body bears a well-developed tracheal system, consisting of a main lateral trunk on each side connected by a transverse ventral trunk in segments 5 to 12, inclusive, and a transverse trunk in segments 2 and 13. A pair of small, open stigmata is located on segment 2 and on each of segments 5 to 12, inclusive, counting the head as segment 1. The duration of this instar is from 23 to 24 hours when the temperature range is 72° to 78° F.

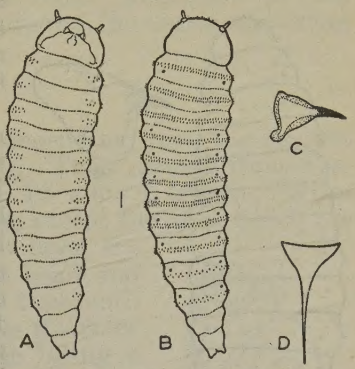

FIG. 2.—*Microbracon mellitor* larva immediately after hatching; A, dorsal aspect; B, ventral aspect, length 1.2 mm.; C, mandible, 0.03 mm. long; D, spine from rings of spines encircling dorsum, length 0.013 mm.

Immediately after molting into the second instar the larva (fig. 3) is 1.7 mm. long, slightly darker in color than the preceding instar, and has a sparse row of minute spines 0.021 mm. long around the middle of segments 2 to 13, inclusive, excepting the ventral portion. On the outer margins of the head and posterior segment are several similar spines. The tracheal system has developed a number of secondary branches, and the stigmata, which are the same in number as in the primary larva, are 0.017 mm. in diameter. The mandibles are proportionately broader, more curved, and are 0.045 mm. from base to tip, which is well chitinized. With a temperature range of 68° to 80° F., the duration of this instar is from 20 to 23 hours.

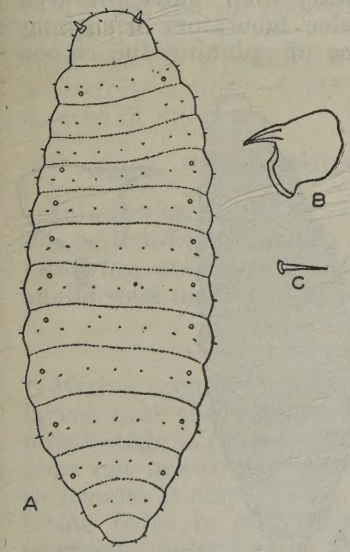

FIG. 3.—*Microbracon mellitor;* A, second-instar larva, dorsal aspect, length 1.7 mm.; B, mandible, length 0.045 mm.; C, spine, length 0.021 mm.

The third-instar larva (fig. 4) is similar in appearance to that of the second, averages 1.9 mm. in length directly after the molt, and bears spines in a similar manner. The stigmata measure 0.021 mm. in diameter, and the mandibles are 0.055 mm. long. Just before molting into the fourth instar its length is increased to about 2.4 mm. The larva remains in this stage somewhat longer than in either of the preceding two, making the duration of the third instar 28 to 30 hours, with the range in temperature from 68° to 80° F.

The appearance of the fourth-instar larva (fig. 5) is distinctly different from that of any previous stage. All the food ingested since hatching is contained within the body. The waste material within the food canal, which is a very dark brown, can be seen through the transparent body walls, making the larva appear dark. The body, except the head

and last segment, is covered with dense pubescence. Each segment and the head bear spines similar to those of the second and third instars. This instar represents the mature larva and averages 4 mm. in length. The stigmata are 0.026 mm. in diameter, and the mandibles 0.07 mm. long from base to tip.

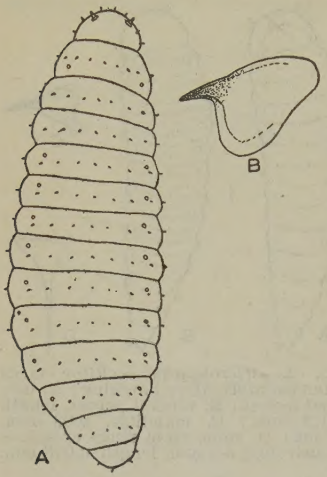

FIG. 4.—*Microbracon mellitor;* A, third-instar larva, dorsal aspect, length 2.4 mm.; B, mandible, length 0.055 mm.

The duration of the fourth instar varies greatly under laboratory conditions. After molting from the third instar the larva feeds from 18 to 20 hours, then detaches itself from the host caterpillar and searches for a suitable location to spin its cocoon. It is during this period, between the time feeding stops and the cocoon is spun, that the variation in length of the fourth instar occurs. The parasite larva, under natural conditions, would be feeding on a caterpillar inclosed in a comparatively small cavity within a cotton boll. In the laboratory the host caterpillar was confined in a small glass vial, 50 by 10 mm. Under natural conditions the larva could find a suitable crevice in which to spin its cocoon much more readily than under the artificial conditions of the glass vial. Under laboratory conditions the time when feeding ceased to the time of spinning the cocoon ranged from 1 hour to 4 days. The duration of the fourth instar ranged from 19 to 115 hours.

The cocoon, which is formed by the mature larva, is semitransparent white, tough and like thin parchment in texture, and is firmly attached to the wall of the cavity in which it is spun. The cavity within the cocoon is about one and one-half times as large as the larva which it contains. The waste material within the food canal, which has been closed posteriorly throughout the larval development, is discharged in the form of a dark brown, thick fluid soon after the cocoon is completed.

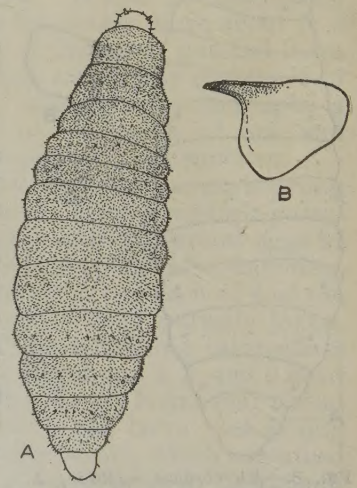

FIG. 5.—*Microbracon mellitor;* A, fourth-instar larva, dorsal aspect, length 4 mm.; B, mandible, length 0.07 mm.

When the waste material has been discharged, the larva enters the quiescent prepupal period. The prepupa is very pale yellow, with slight contractions dividing the head, thorax, and abdomen, causing it to assume somewhat the form of the pupa. The eyes of the pupa show through the integument as two light-brown spots. After remaining in this state for 20 to 28 hours the

last larval skin is cast. In the process of this molt the skin splits along the dorso-cephalic portion of the body and is worked off posteriorly by an undulating motion of the body. The whole process of molting is accomplished in about five minutes, the exuvia remaining at the posterior tip of the abdomen.

PUPA

The size of the pupa (fig. 6) varies, depending upon the amount of food available in the host caterpillar. Those reared from *Pectinophora gossypiella* ranged from 3 to 4.5 mm. in length. When first formed, the pupa is glistening white, except the eyes, which are dark reddish brown. About two days later the more heavily chitinized portions of the head and thorax become dark orange. From this time until emergence the whole body slowly assumes the color of the adult. The adult emerges after biting a hole in the end of the cocoon. The duration of the pupa stage in the laboratory was 3½ to 4 days, with a range in temperature of 76° to 86° F., and 4½ to 5½ days with the temperature range 71° to 80° F.

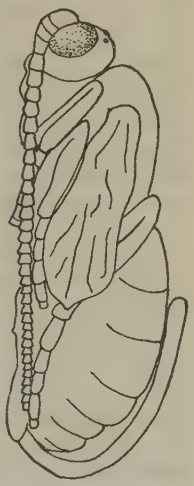

FIG. 6. — *Microbracon mellitor;* female pupa, length 4.5 mm.

The life cycle of *Microbracon mellitor*, in the laboratory, may be as long as 4 months. The maximum egg, larval, prepupal, and pupal periods were 28, 187, 28, and 132 hours, respectively, or a total of approximately 16 days. One adult lived for 102 days, making a possible life cycle, under favorable laboratory conditions, 118 days, or a little under 4 months in duration.

PERISIEROLA EMIGRATA

In addition to the brief notes on the biology of this bethylid published by Busck (*3, p. 359; 4*), the following observations on oviposition and on the habits of the adults were made by the writer.

MATING

Mating occurs within the cocoons, which are spun by the mature larvae near the remains of the host caterpillar, and in which the pupal stage is passed. The males in each group of cocoons emerge from one to two days before the females. The proportion of males to females is about 1 to 4. The males gain access to the females by biting holes in and entering the cocoons. These holes serve as emergence holes for the females, subsequent to mating. Large numbers of adults were under observation, but no attempts to mate were observed after the females had emerged. Many instances of mating within the cocoon of the female were distinctly seen through the binocular microscope.

PARTHENOGENESIS

Busck (*3, p. 360; 4*) records breeding four generations of *P. emigrata*, which were all females, from a single unfertilized female. By

following his procedure, isolating the parasites by placing cocoons soon after they are formed in individual glass vials, the writer was unable to obtain similar results. Nine females so isolated, and consequently having no opportunity to mate, were supplied daily with caterpillars of *P. gossypiella* until they died. These females deposited 1,413 eggs, from which were reared 1,198 males and no females.

OVIPOSITION

Eggs are deposited usually upon the full-grown caterpillar, but never until it has been paralyzed. When the host caterpillar is located the parasite pounces upon the back of its victim, runs to the anterior end, takes a firm hold with its mandibles just back of the head, curves its body around the caterpillar and stings it in the throat just back of the mandibles. The process of stinging has been observed many times, and the procedure is nearly always the same. Occasionally the caterpillar is stung on the posterior end first, enabling it to bend back and bite the parasite, sometimes killing it and often severing a leg. The loss of a leg causes the parasite to make no further attack upon the caterpillar inflicting the injury, or upon any other. The sting causes the caterpillar to struggle and writhe violently at first, but it gradually becomes more quiet, until, in about five minutes, paralyzation is sufficient to induce the parasite to oviposit. Even after the eggs have hatched and the parasite larvae have grown to considerable size, the caterpillar is capable of slight movement.

Before depositing its eggs, the parasite ascertains the degree of paralyzation of its host by biting and pulling at the skin. The eggs are deposited in longitudinal rows on any part of the body. Oviposition of parasites in confinement begins about five days after emergence. Of 10 females, 3 began oviposition four days after emergence, 6 five days, and 1 six days. The maximum number of eggs deposited upon one caterpillar by a single female in one day was 29; the average number on each of 247 caterpillars was 14.8.

TABLE 4.—*Daily rate of oviposition of Perisiero'a emigrata on larvæ of Pectinophora gossypiella*

Date of oviposition	Eggs deposited by female No.									
	1	2	3	4	5	6	7	8	9	10
1919										
May 15	16	15	19	14		18		19	15	17
16					11		25			
18	17	14	18	16		17		16	17	17
19					14					
20							23			
21	19	15	16	17		16			13	17
23					19			21		
24	18	18	21	15		19	21		19	16
25			11							
26					20					
27	19	16				17	20			16
28			17	14					20	
29					18	10	10			5
31	22	(1)		13						19
June 1			22		18	17			23	
3	16			14						12
4			11		18	17	17	(2)		

[1] Escaped. [2] Died.

TABLE 4.—*Daily rate of oviposition of Perisierola emigrata on larvæ of Pectinophora gossypiella*—Continued

Date of oviposition	Eggs deposited by female No.									
	1	2	3	4	5	6	7	8	9	10
1919										
June 5									18	
6	11									13
7					15					
8			18	16		14				12
9					12		(2)		19	
10	15			14		14				
11			19							14
12	16				12					
13				8		15			16	
14	18		11							15
15				17						
16					(2)	12			18	12
17			17							
20	11		14			11			20	16
21				(2)		(2)			(2)	
23	8									18
24	(2)									
29			3							17
30			(2)							(2)
Total	206		217	158	157	197	116	56	198	236

[2] Died.

Females confined in glass vials and fed daily with honey and water may survive over seven weeks and deposit many eggs throughout their lifetime. Ten females, kept under these conditions and given a constant opportunity to oviposit, survived as follows: 24, 29, 37, 41, 42, 42, 45, 50, and 51 days, respectively; and one escaped. Table 4 gives the daily rate of oviposition and the total number of eggs deposited by these 10 females. The data in this table show that oviposition, under laboratory conditions, may occur readily throughout the life of the insect. Five of the 10 deposited eggs the day before death, one producing 20 and another 17 eggs. The minimum number deposited was 56 by female No. 8, and the maximum number 236, by No. 10. It is interesting to note the uniformity of the intervals beween the deposition of the different batches of eggs. The duration of these intervals was 3 days in 57 instances, 4 days in 16, 2 days in 13, 6 days in 2, and in 1 instance each it was 1, 5, and 9 days. Host caterpillars were available at all times, and the interval between oviposition of the different batches of eggs by each insect was three to 4 days in the great majority of instances.

SUMMARY

The pink bollworm (*Pectinophora gossypiella*) has been reared in Hawaii from several species of cotton (*Gossypium* spp.), milo (*Thespesia populnea*), *Hibiscadelphus hualalaiensis*, and *Hibiscus youngianus*. Cultivated cotton is heavily attacked by this moth. One lot of 22 bolls contained an average of 5.1 pink bollworm caterpillars per boll, and the total number of bolls, 8,744, collected during 1918 and 1919, produced an average of 1.5 caterpillars per boll. The seed pods of *T. populnea* are frequently found infested, but the infestation is not heavy. *H. hualalaiensis* and *H. youngianus* are not abundant in Hawaii and only occasionally are found infested.

P. gossypiella is attacked in Hawaii by seven species of parasites, as follows: *Chelonus blackburni* Cameron, *Microbracon mellitor* Say (*M. pembertoni* Bridwell), *Pimpla hawaiiensis* Cameron, *Pristomerus hawaiiensis* Ashmead, *Perisierola emigrata* Rohwer, *Chalcis obscurata* Walker, and *Stomatoceras pertorvus* Girault. None of these is a specific parasite of *P. gossypiella.* Each one has been reared from several other species of moths in Hawaii, while *P. hawaiiensis* and *C. obscurata* have been reared from 10 and 13 different hosts, respectively. This diversity of hosts is largely responsible for the low degree of control of *P. gossypiella* exerted by these parasites. Only 8.42 per cent of 12,985 caterpillars, under observation during 1918 and 1919, were parasitized by the combined efforts of the 7 species.

Microbracon mellitor is considered the most effective parasite of *P. gossypiella* under Hawaiian conditions, because of its general distribution throughout the area under observation and various factors in its biology. The adult is hardy and able to maintain itself under adverse conditions, and its capacity for oviposition is good. One female deposited 213 eggs before death. The maximum period from the oviposition of the egg to emergence of the adult was 16 days.

Mating of *Perisierola emigrata* was observed to occur only within the cocoon of the female. The adult female is capable of ovipositing throughout her lifetime, and one female deposited 236 eggs. Parthenogenetic reproduction was observed with this species, but only males were produced. From 1,413 unfertilized eggs under observation, 1,198 males and no females were reared.

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III. 6

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